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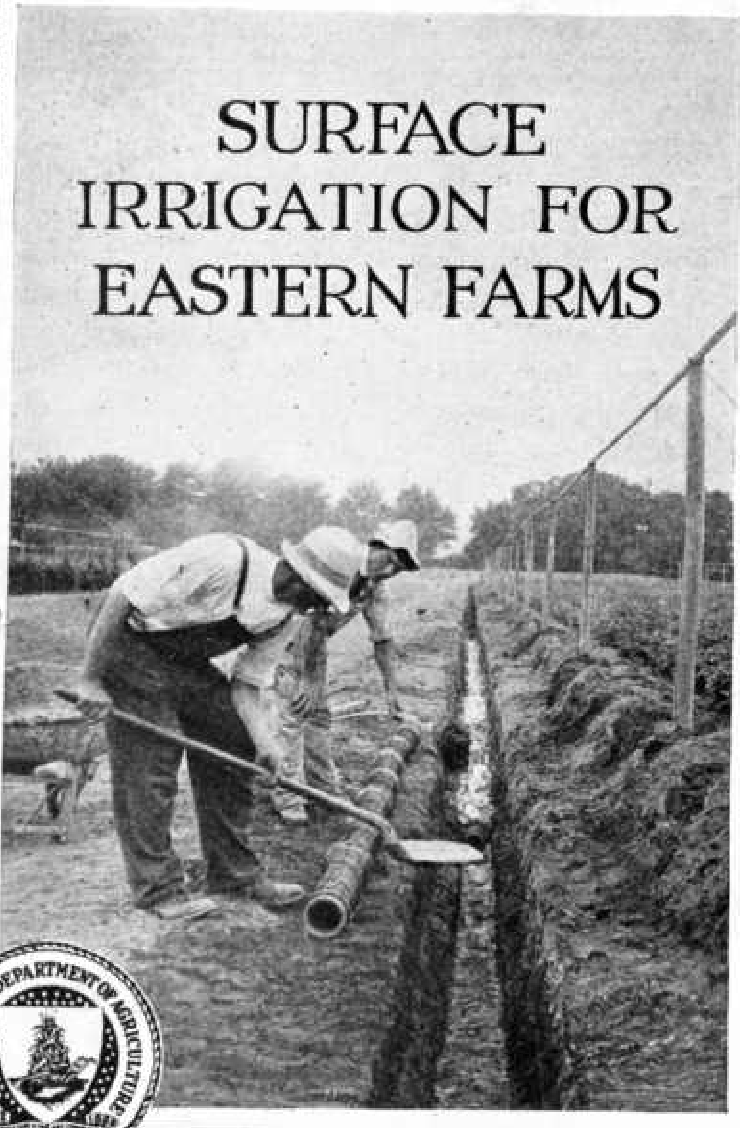
SURFACE IRRIGATION FOR EASTERN FARMS



IRRIGATION for the protection of valuable crops on eastern farms, which has been much encouraged in recent years, has been confined very largely to two methods, spray irrigation and subirrigation. Both systems are expensive, and subirrigation seldom is satisfactory except under peculiar soil conditions. This bulletin explains the methods of surface irrigation, which are simpler and less expensive than either the spray or the subirrigation method and may be adapted to eastern farms.

The information should be helpful to farmers who have been discouraged from undertaking irrigation by the high cost of spray and subsurface methods, in spite of their belief that it would result in material increases in their crop yields.

Washington, D. C. Issued December, 1917; revised September, 1924

SURFACE IRRIGATION FOR EASTERN FARMS

By F. W. Stanley, *Senior Irrigation Engineer, Bureau of Public Roads* [1]

CONTENTS

THREE methods of irrigation are popular in sections of the Eastern States where conditions justify the artificial application of water to growing crops. These are known as the spray, the subirrigation, and the surface methods.

By the first method water is applied to crops in the form of a fine spray. It is adaptable to any topography or type of soil. The water is supplied under pressure, which is provided by an individual pumping plant unless city mains are tapped. The distribution system of the most common type of spray plant costs from $125 to $250 an acre. The main pipe line running from the water source to the field, together with the pumping plant or connection to a supply main, involves additional expense. The type of system just referred to for 5 to 10 acre units, pumping from wells or streams to adjacent lands, calls for initial expenditures ranging from $200 to $300 an acre, and sometimes more. Thus the crop which will justify irrigation by this method must be of sufficient value to warrant the financial outlay necessary for an irrigation plant and be increased in selling value by irrigation $60 or $75 per acre per year, which will pay interest at 6 per cent on the cost of pumping equipment and distribution system, 7 per cent depreciation of materials, and maintenance and operation expenses. All this indicates the necessity for highly intensive farming, sure markets, and ability to produce and handle a high-grade crop.

Subirrigation, which consists of the application of water to the soil through porous pipe or tile laid underground, is a method which can not be employed successfully under ordinary soil conditions. The chief requisite for subirrigation is a porous surface soil and an impervious subsoil which tends to hold the irrigation water within the root zone of the plants. Even where this exceptional soil condition exists it is seldom advisable to install a subirrigation system

[1] Revised by F. E. Staebner, Drainage Engineer.

NOTE.—Prices of pipe, pumps, and equipment given herein are those quoted early in 1924.

because of the high first cost, the tendency of roots and silt to enter and clog the pipe, and the relatively large amount of water required.

The high expense involved in both spray and subirrigation systems has discouraged many farmers from undertaking irrigation. This bulletin discusses the so-called surface methods of irrigation and their possibilities for the farmer whose pocketbook, crops and market facilities do not justify consideration of the other methods.[2]

CONDITIONS ADAPTED TO SURFACE IRRIGATION

Surface methods of irrigation are of two general types, furrow and flooding, both of which are used extensively in the arid sections of the United States. In the East the flooding method is seldom employed, since small-grain crops and meadows, to which this method is best adapted, are not ordinarily irrigated. This method requires a nearly level ground surface, and eastern soils are seldom deep enough to permit of much grading. However, if fields can be leveled properly and water can be applied cheaply enough, there is no reason why the flooding method should not be employed.

The furrow method is used for the irrigation of cultivated row crops and orchards. The citrus groves of Florida are irrigated extensively by this method.

Many farms are adapted to a combination of spray and furrow methods, the spray irrigation being applied to seed beds, quick-growing market garden crops, berries, and crops grown on rolling lands which are not well adapted to furrow irrigation, while crops on even slopes which are cultivated with horse-drawn implements may be advantageously irrigated from furrows.

It must be remembered, however, in comparing the spray and surface methods that the uniformity of distribution possible with the former can not be attained with the latter and that the labor of watering a field by surface methods usually is much more than that necessary in the operation of a spray plant.

AMOUNT OF WATER NEEDED IN FURROW IRRIGATION

Ordinarily irrigation in the humid sections is undertaken mainly for insurance against loss from drought. Therefore, the chief consideration is that the plants receive enough water to keep them in good condition until the next rain. It is not often practicable to irrigate crops by running water in furrows and apply less than 1 acre-inch per acre each irrigation. One acre-inch per acre is equivalent to 1 inch of rainfall, or 27,152 gallons. Measurement of water on heavy soils containing considerable clay shows that about this amount is required for an average irrigation; twice or three times as much may be required to irrigate sandy soils. In general, the limits may be placed between 25,000 and 60,000 gallons. In many instances the use of portable pipe, described later in this bulletin will effect a considerable saving in water.

[2] Spray Irrigation, Bulletin No. 495, U. S. Dept. Agr., discusses in detail the various methods of irrigation by spraying now practiced in the Eastern and Southern States. A description of the subirrigation systems of Florida, where this method has had its most notable success, is contained in Irrigation in Florida, Bulletin No. 462. U. S. Dept. Agr.

The acreage irrigated, then, will determine the total amount of water needed, and the time taken to apply this water will determine the quantity of water needed per unit of time. For instance, if a farmer wishes to irrigate 1 acre of stiff soil, and can irrigate 12 hours a day, he will probably need about 25,000 gallons, or about 2,000 gallons per hour, if he irrigates the whole piece in one day. If he is content to water one-fifth of an acre a day he will need only 400 gallons per hour, or 6.6 gallons per minute. If the water supply is limited, it may be necessary to extend the irrigation over a period of 10 days or two weeks. Assuming the latter period, he will need 25,000÷14=1,786 gallons per day, or about 2.5 gallons per minute, irrigating 12 hours a day. If the soil is sandy and the grades are flat, he may need twice this amount. As a matter of fact, it is an exceptional case where so small a quantity of water can be used by surface methods unless storage is available, the foregoing computation being made merely to show the process of determining the water required.

For a larger acreage the same method of computation is followed. For instance, if 10 acres of tight soil is to be irrigated, multiply the above figures by 10, which will show that from 25 to 60 gallons per minute will be needed for 14 days of 12 hours each. In many cases it is necessary to figure on irrigating 24 hours a day in order to utilize a limited water supply, or to cut down the size of the pump. In such cases only one-half of the quantity per minute called for above would be required, but the total amount would be the same or probably more, as it is difficult to prevent a waste of water when irrigation is undertaken at night.

Where the water is taken from streams and can be carried to the land by gravity, the quantity is not of so much importance as when it must be pumped, since in the latter case the supply is apt to be limited and the cost of pumping comparatively heavy. In many instances large acreages can be irrigated very cheaply where gravity supplies are easily accessible, but favorable conditions of this sort are seldom found in the East.

OBTAINING A WATER SUPPLY

The item to be considered first in planning a furrow-irrigation plant is the water supply. This must be near enough to the land to justify the cost of putting in the pipe line or ditch to carry the water. In most cases in the East it is not practicable to divert water directly to the land from a stream, as is done frequently in the West, because such a diversion must be made at a point high enough upstream to permit the water to flow down the ditch to the land to be irrigated. In many instances this would require a ditch of considerable length, even when the irrigated farm is not large; and where the land which must be crossed by the ditch is of much value or belongs to other farmers the obstacles in the way of constructing a gravity system are serious. Therefore a pumping plant is a common adjunct to the irrigation system, whether the source of supply be a well, stream, or lake. Usually it does not pay to pump water through a vertical lift of more than 100 feet for the ordinary field crops, although valuable truck crops may justify a lift of over 200 feet. If the water is near the land to be irrigated, the main pipe or

ditch need not be very expensive. A long pipe line is costly, however, and the economical limit of length is soon reached for most field crops.

If water is pumped from streams or lakes the installing of pumping machinery is simple, unless there is danger of floods or the banks are unusually steep. The pump, unless it be of the plunger type discussed on page 9, must always be placed within suction lift of the water supply, which for practical purposes is under 25 feet. Where there is danger of floods, it is best to place pump and engine on skids or wheels so that they can be moved quickly and easily. Tractors are well suited for furnishing power in such cases. (See fig. 1.)

FIG. 1.—Horizontal centrifugal pump operated by a tractor

If the water supply of the stream is not sufficient, conditions may permit the making of a small storage reservoir [3] by building a dam at some suitable point. Small quantities of water pumped by rams or windmills may be used to water small patches when used in conjunction with reservoirs. Springs sometimes yield enough water for irrigation, and when favorably located may permit the water to be conveyed to the land by gravity. Usually such sources yield small quantities of water and will serve only small areas.

If a stream falls fairly rapidly and carries an abundant supply of water, its own power may be used to lift a supply to the land. A hydraulic ram or water wheel and pump is used in such a situation. Such devices have the advantage of low operating cost, and often may serve other purposes beside pumping. Many water wheels, for example, used for milling or cotton ginning, could be made to operate

[3] Various types of small reservoirs which should be of interest to readers of this bulletin are discussed in Bulletin No. 179, Office of Experiment Stations, and Farmers' Bulletin No. 828. The department's supply of Bulletin 179 has been exhausted, but copies can be obtained from the Superintendent of Documents, Washington, D. C., for 20 cents. Farmers' Bulletin No. 828 is available for free distribution by the department.

pumping machinery also. Water-power devices for pumping purposes only are often a great deal more expensive than power pumps, however, and in many cases are subject to washout during high water. Moreover, many hydraulic rams now in use do not deliver enough water for irrigation purposes. The large sizes chiefly used for irrigation are expensive, and are more adaptable to western conditions than to those where irrigation water is needed only a small portion of the time.

Wells are a common source of supply for irrigation purposes. Several types are used: The dug or open well is of much use in some sections, but for the most part the amount of water made available

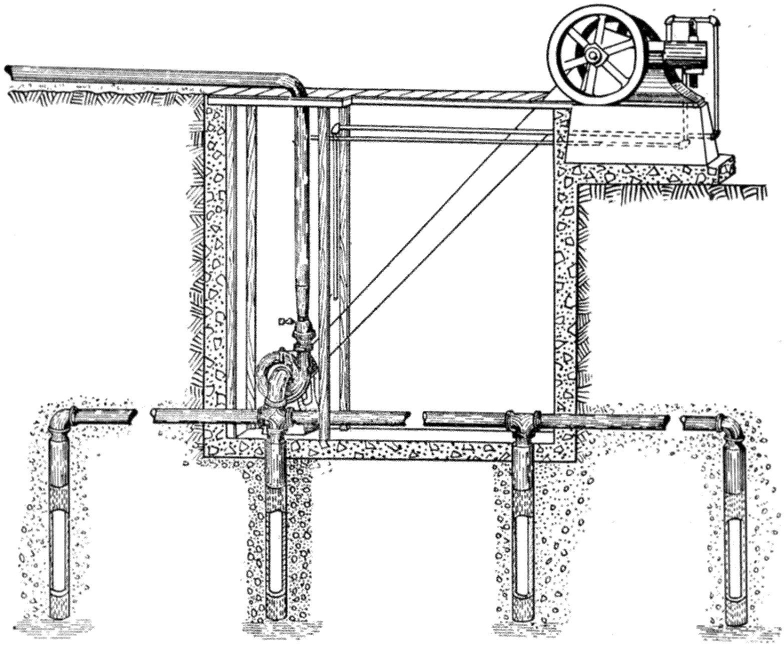


FIG. 2.—Horizontal centrifugal pump set in concrete pit, to pump from several connected wells. Pit is required because the suction lift from the gravel surface is more than 25 feet

by it is too small for any but domestic use. Dug wells are affected considerably by droughts, and often are dry or nearly so when water is needed most.

Drilled or bored wells often yield large amounts of water. Some wells of this type flow and provide sufficient water to irrigate several hundred acres. Most drilled wells do not flow, however, although many of them will yield liberally when pumped. It is a comparatively easy matter to pump from bored wells when the water stands within 25 feet of the surface, but to obtain large irrigating heads when the water is 30 feet or more below the surface would require expensive pumping equipment. Small quantities, however, can be pumped from such wells at a moderate cost.

Driven wells also are used for irrigation purposes, and are a cheap source of water where the lift is less than 25 feet. One 2-inch well usually will yield from 10 to 40 gallons per minute, if the point is

driven in a good sand or gravel water-bearing stratum. A large number of points may be driven and connected to one central pump. Where this is done it is common to place the well points from 25 to 50 feet apart. If the water-bearing stratum is more than 25 feet below the surface, the same method often can be followed by digging trenches, laying the connecting pipes in them, and setting the pump in a central pit. The pit and the connecting trenches must be deep enough to reduce the vertical suction distance to 25 feet or less (fig. 2).

CONVEYING THE WATER TO THE LAND

The conveyance of water from the source of supply to the land usually is one of the most difficult problems that face the irrigator. If the supply source is wells, either flowing or pumped, located at the highest part of the farm, the water can be carried to the furrows by open ditches at very little cost. Often water will rise as high in a well at the higher elevations of the farm as at the lower, but if a pumped well at a lower elevation within suction lift would yield sufficient water, while a well on the higher elevation would require a deep-pump pit, it might be cheaper to drill the well at the lower point and force the water to the higher elevations through a pipe line.

If water is to be diverted from a stream by means of an open ditch, the proper size of the ditch and its grade or fall in inches per 100 feet of length must be determined before excavation is commenced. The size of the ditch will depend for the most part on the acreage to be watered. Usually the grade is kept as flat as is practicable, so as to retain a good elevation at the point of delivery. If the diversion point from the stream is high, the grade of the ditch must be determined by the character of the soil, for if the grade is made very steep in order to cut down the size of the ditch trouble from washouts is likely to result, especially if the soil is sandy or if the ditch has been carried along a hillside or across earth fills.

A small ditch can be carried on a steeper grade than a large one, owing to greater friction. Several influences enter into the exact determination of the friction factors in mathematical formulas used by engineers in designing open ditches, but, generally speaking, wide, shallow ditches, with rough and irregular sides and bottom, crooked and subject to many changes of grade, will not carry nearly as much water as straight, deep ditches of regular outline. Table 1 shows common shapes and sizes of farm ditches with permissible grades to carry given amounts of water.

TABLE 1.—*Discharges of ditches with different grades*

Dimensions of ditch				Grade in inches per 100 feet	Discharge
Top width	Bottom width	Depth	Area of cross section		
Feet	*Feet*	*Feet*	*Sq. feet*		*Galls. per min.*
1.5	1	0.5	0.6	2.00	300
3.0	2	1.0	2.5	.50	800
4.5	3	1.5	5.6	.25	1,600
6.0	4	2.0	10.0	,20	3.500
11.0	8	3.0	28.5	.12	9,000

This table shows sizes and grades for ditches designed to carry water at a safe velocity for average soils. The shapes are for practical ditches and can be followed safely for ordinary heads. It should be noted how rapidly the grades diminish as the quantity of water to be carried increases. The velocities are nearly the same in all the ditches, a slightly greater velocity being allowed for the small ditches than for the larger ones. If the grades are taken appreciably flatter than those given above for similar amounts of water, the water is apt to run too sluggishly, so that weeds and silt soon will tend to clog the ditch.

In such a situation as that just outlined the expense of irrigation should be small, unless a substantial diversion dam or a long main ditch is required. On the other hand, if the distance from the source to the land is considerable, a pipe line also would be too expensive, and a cheaper plan would be to install a pumping outfit on the bank of the stream, the pump being set as near as possible to the land to be irrigated.

DETAIL OF PUMPING PLANT

Where water is pumped from streams or other open bodies of water, a centrifugal pump usually is the cheapest and best type for surface irrigation. The advantages of a centrifugal pump are its low cost, light weight, lack of valves and parts that wear out easily, comparative ease of operation and maintenance, and relatively high efficiency in raising large quantities of water through moderate lifts.

The single-stage horizontal is the type of centrifugal pump in most common use for irrigation, being especially adapted to pumping quantities of water above 250 gallons per minute from streams or from wells where the suction lift is not over 25 feet. If the water from a well must be lifted from 25 to 40 feet, this pump usually can be set in a pit and belt-connected to an engine at the ground surface. If electric power is available, it often is possible to dig a pit and set the pump directly connected to the motor at the bottom. Horizontal centrifugal pumps are made in several stages, depending on the lift. The ordinary single-stage pumps are made to pump water through total lifts up to 125 feet. Pumps of more than one stage will lift water to considerable heights, but they are much more expensive than those already referred to.

Another type of centrifugal pump used for irrigation purposes is the vertical centrifugal. (Fig. 3.) This differs from the horizontal type in that the impellers are operated by a vertical shaft, which may be of considerable length. This type is used almost exclusively for pumping from wells where the water table is below the permissible suction lift, as the pump may be set in a deep pit below the ground-water level and operated by a belt-driven pulley on top of the vertical pump shaft. Vertical centrifugal pumps cost about 50 per cent more than horizontal pumps of the same capacity. To the cost of the pump itself must be added the cost of pump pit and framework which contains the vertical shaft. The vertical type usually requires about 10 per cent more power than the horizontal.

Several types of centrifugal pumps are constructed for pumping water from deep wells, where the suction lift is too great to allow the

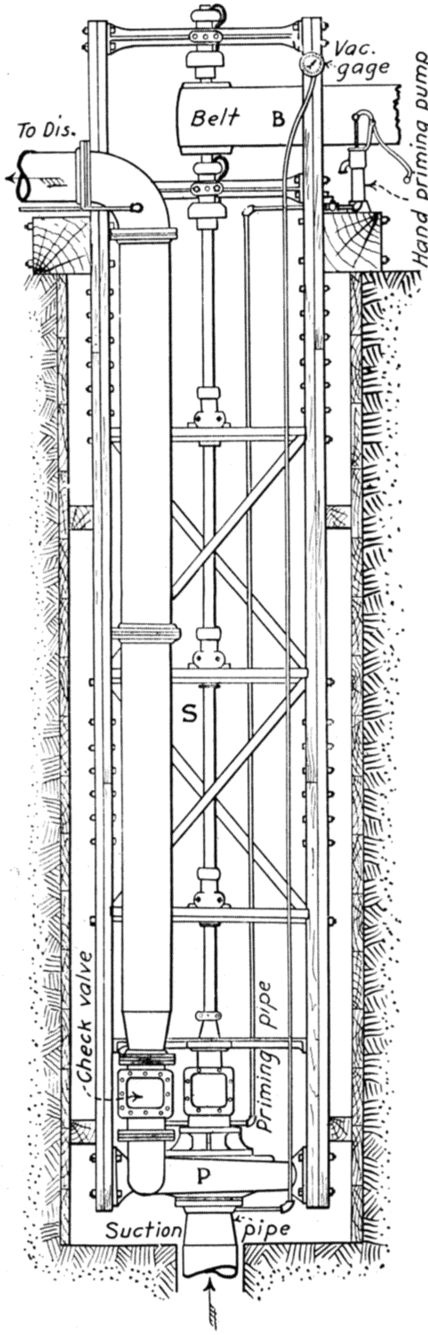


FIG. 3.—Vertical centrifugal pump in pit. Pump P is operated through vertical shaft S by means of half-turned belt B

utilization of pits dug by hand. These usually are called deep-well turbine pumps. (Fig. 4.) They are similar in general principles to the vertical centrifugal type, with impellers incased in a shell, but are so constructed that they can be let down to any required depth in drilled wells of large bore. Wells 12 inches and more in diameter may be pumped by this type. If a deep well of less than 12 to 15 inches diameter is to be drilled, it is common to bore a larger well to the water level. This will contain the pump. The well of smaller bore then is started and may be bored to a great depth. Deep-well pumps of large capacity are expensive, costing from five to ten times as much as horizontal centrifugal pumps. To the cost of a pump of this type must be added the extra cost of boring and casing the larger well containing the pump. Deep-well pumps are efficient when delivering quantities of 500 gallons per minute or more and are moderately free from trouble if properly installed.

Water often may be raised successfully from deep wells with high lifts by means of the so-called air lift. This apparatus includes an air compressor which forces air into the water near the bottom of the well. Released there the air seeks to rise to the surface, and in doing so forces a quantity of water from the well. One compressor may supply air for several wells, as the air may be piped a considerable distance from a central power house. The advantages of the air lift are the absence of complicated apparatus beneath the ground surface, and the ease with which a large number of wells may be pumped from one central station. This

type is adapted especially to deep-well pumping where the water supply is uncertain. However, this pump usually is less efficient than the centrifugal type under moderate lifts, and is more costly. It usually is more efficient if operated by steam than by gas engine.

The ordinary plunger pump commonly used on the farm to raise water for domestic purposes may be utilized in irrigating small areas. This pump is adaptable to nearly all conditions, and is especially useful for pumping water from wells where the lifts are high. Plunger pumps are made in many types to pump widely varying quantities of water, these falling, however, into three main groups—with single cylinders (simplex), two cylinders (duplex), or three cylinders (triplex). Each of these forms may be either single or double acting. For quantities of water up to 100 gallons per minute, the single-cylinder or duplex pumps are satisfactory and more efficient than centrifugal pumps. For quantities from 100 to 200 gallons per minute, the plunger types are rather expensive when compared with the centrifugal, but their higher efficiencies often recommend their use in spite of this fact. Where more than 250 gallons per minute is to be pumped, it usually is best to install a centrifugal pump, as the cost is very much lower than that of the duplex pump. A triplex pump practically never should be used for surface irrigation unless the lift is great or the pump is to be used for other purposes in addition to irrigation.

Plunger pumps are recommended where water is pumped

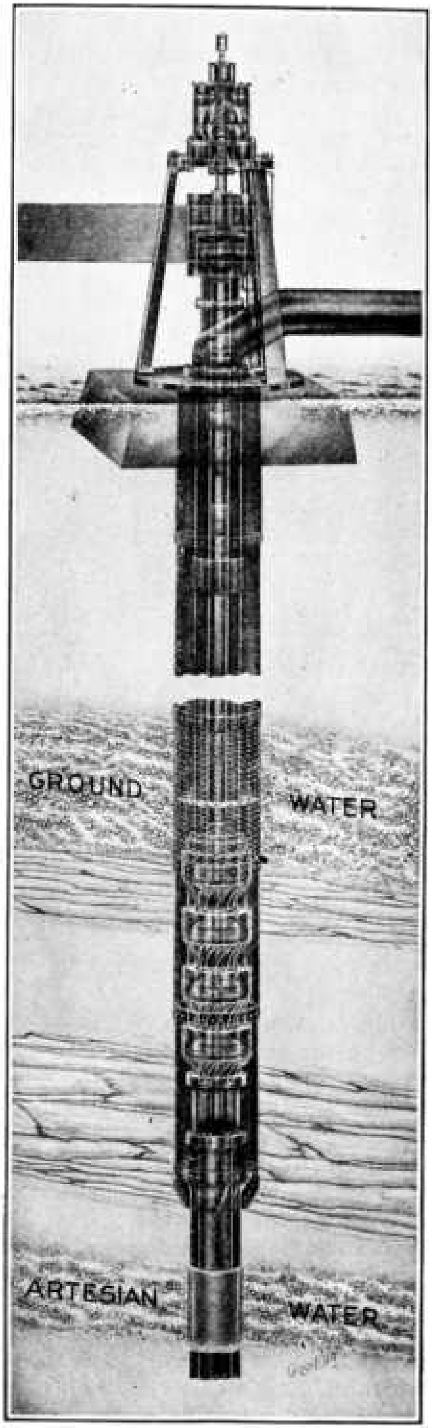


FIG. 4.—Deep-well turbine pump, operated by half-turned belt

from a battery of driven wells if a shortage of water is likely to occur, as they are self-priming. The centrifugal pump must be primed, unless submerged, and the suction pipe must be air-tight.

Since centrifugal pumps are designed for known constant lifts and run most efficiently against those lifts, pump companies from whom cost estimates are desired should be informed regarding the lift and other conditions, and the specifications finally accepted should be adhered to closely in installing the pump. Plunger pumps may be operated under varying speeds and heads, but, as in the case of the centrifugal type, the maximum efficiency will be obtained under the conditions for which the pump is designed.

Nearly all centrifugal pumps are fitted with pulleys and are belt-connected to gasoline engines, electric motors, or other sources of power. Direct connection is advisable, however, wherever practi-

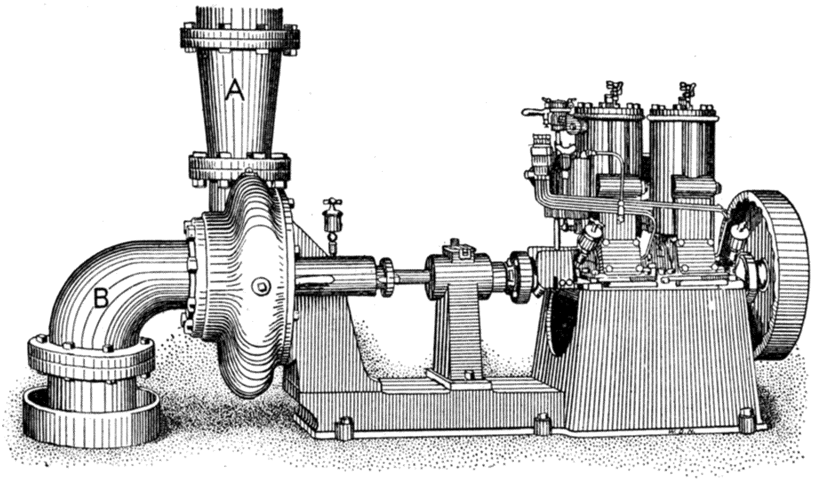


FIG 5.—Horizontal centrifugal pump direct-connected to 2-cylinder marine engine. A shows discharge and B suction pipe. Note taper of both

cable, since by it loss of efficiency by belt slippage is eliminated and the outfit is made much more compact. The power will, of course, depend upon local conditions.

The most common power source is some form of internal-combustion engine. (Figs. 5 and 6.) Many engines still use gasoline for fuel, but nearly all of the new farm engines are fitted to burn kerosene, and some burn the heavier oils very successfully. Small engines generally are best fitted to burn kerosene. For an engine of 20 horsepower or more it sometimes is advisable to fit the engine with a gas-producer apparatus, so that the heavy fuel oils may be used; but it must be remembered that an engine used for irrigation purposes only will be operated for short periods in most parts of the humid sections. A possible saving in expense for fuel therefore is likely to be unimportant, inasmuch as the expenses incurred in installing a heavy-oil engine may far offset it.

The cost of gas engines varies widely. Those adapted to small irrigation systems, with from 1 to 5 horsepower, should cost from

$25 to $40 per horsepower; 5 to 25 horsepower engines should cost from $15 to $50 per horsepower. The cheaper grades are recommended for most plants used for furrow irrigation in the Eastern States on account of the short periods during which they are operated.

As in the case of the pump, the engine used in connection with an irrigation plant in the Eastern States often may serve other purposes, especially if it is portable. If the engine is already serving other purposes when the pumping plant is installed, the pump must be adapted to the engine, instead of the reverse, as is usual.

Steam engines usually are economical where wood fuel is plentiful, as is the case in many sections of the South where pine is abundant. However, for the plant of less than 25 horsepower it seldom is economical to purchase a new steam-pumping outfit, as the initial cost of steam engines is considerably more than that of gas engines, and they require more labor for attendance. If electric current is

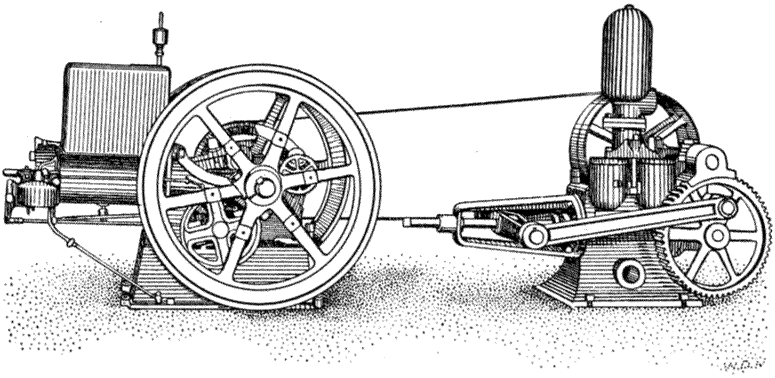


FIG. 6.—Gasoline engine belt-connected to single cylinder, double-acting power pump

available at moderate rates, motors will prove very satisfactory, operating with a minimum of trouble. If a flat rate is charged for power, however, the operating charges may be prohibitive.

The size of the pump will depend on the time allowable for the irrigation of the area to be watered. The horsepower required to operate the pump depends on the quantity of water to be lifted, the elevation of the land above the water source, and the distance the water must be carried in a pipe.

The following table shows the amounts of water needed to irrigate different acreages in reasonable time. If the amount of water which is needed is known, the size of the pump and the power needed to operate it may then be ascertained. The total horsepower required will be found by multiplying the number found in the table by the total lift. The total lift will be the actual lift from the water surface to the highest part of the farm plus the loss due to friction. The friction loss, shown by column 7 of the table, depends upon the size and length of the pipe. This is shown in feet per 100 feet of main pipe line. Data in Table 2 apply to favorable conditions of soil and grade where the total lift is not more than 100 feet.

TABLE 2.—*Sizes of pumps and engines required for the irrigation of different areas*

Area	Water required per 2-inch irrigation	Capacity of pump per minute	Size of pump [1]	Kind of pump	Size of discharge pipe	Friction loss in discharge pipe per 100 feet	Efficiency of pump	Horsepower of engine per foot of lift	Approximate cost of pump: 20-40 feet head	Approximate cost of pump: 50-100 feet head
Acres	*Gallons*	*Gallons*	*In. or No.*		*In.*	*Feet*	*Per ct.*		*Dols.*	*Dols.*
¼	13,500	10	3 by 4	Single cylinder double acting plunger.	1½	1.43	30	0.01	110	
½	27,000	10	3 by 4	...do......	1½	1.43	30	.01	110	
1	54,000	20	4 by 4	...do......	2	1.82	30	.015	125	
2	108,000	35	5 by 5	...do......	2½	1.72	30	.025	190	
3	160,000	35	5 by 5	...do......	2½	1.72	30	.025	190	
4	210,000	55	6 by 6	...do......	3	1.6	35	.040	220	
5	270,000	110	6 by 12	...do......	4	1.45	40	.070	400	
			or No. 2	Centrifugal	4	1.45	30	.85	45	110
10	540,000	225-265	3	...do......	6	0.74-1.06	35	0.166-.195	65	130
15	800,000	300-375	4	...do......	6	1.29-2.00	40	.185-.231	90	225
20	1,000,000	400-500	4	...do......	8	.56-.81	40	.247-.309	90	225
25	1,300,000	700-750	5	...do......	8	1.54-1.74	45	.39 -.418	100	300
30	1,500,000	700-750	5	...do......	8	1.54-1.74	45	.39 -.418	100	300
40	2,000,000	900-1,100	6	...do......	10	.83-1.20	50	.456-.558	125	400
50	2,700,000	900-1,100	6	...do......	10	.83-1.20	50	.456-.558	125	400
75	4,000,000	900-1,100	6	...do......	10	.83-1.20	50	.456-.558	125	400
100	5,400,000	1,200-1,500	8	...do......	12	.57-.85	55	.55 -.68	235	500
200	10,800,000	1,600-2,200	8	...do......	12	1.00-1.69	55	.73 -1.0	235	500

[1] Double-acting plunger pumps are sold by diameter of the plunger, in inches, and the length of stroke, in inches, which are the dimensions shown here. Centrifugal pumps are sold by number, which describes the diameter of the discharge pipe, in inches, at the pump. Purchasers should secure a manufacturer's guarantee that the pump actually has the capacity represented under the given conditions

To illustrate the use of Table 2, assume that it is desired to irrigate 10 acres, that the highest point of the land is 40 feet above the water supply, and that the pipe line from the pump to the land is 1,200 feet long; then from the table see that a No. 3 centrifugal pump will be needed to supply this. To determine the horsepower needed to operate the pump determine first the total lift, which will amount to the difference in elevations, 40 feet, plus the friction loss. If 5-inch pipe is used, the friction loss in it will be equivalent to 1.5 foot of lift for each 100 feet of pipe. There being 1,200 feet of pipe, the friction loss will be $12\times1.5=18$ feet; so that the total lift to be considered will be $40+18=58$ feet. The total horsepower called for will then be $58\times0.16=9.3$, this being at the rate of 0.16 horsepower for each foot of lift. A 10-horsepower engine would be recommended for this plant.

In many cases it would be possible to use smaller discharge pipe than the sizes recommended in Table 2; but if that were done, higher power would be required to force the water through it. Where conditions require the use of smaller pipe the matter of specifications would better be referred to the pump or engine manufacturers, to the Department of Agriculture, the agricultural experiment station of the State in which the farmer lives, or to a local engineer. The table can not be made to apply to all possible conditions, of course, but should give a basis for computing the probable cost of an irrigation plant.

Details of the installation of pumps and engines can not be entered into here. Generally speaking, suction and discharge pipe should be

large enough to reduce friction loss to a minimum and all unnecessary sharp bends should be eliminated. Where possible to do so it always is best to consult a pump expert before installing a plant. Companies manufacturing pumps usually are prepared to give advice on such details and in many cases will oversee the installation.

DISTRIBUTING THE WATER

The control of water from the larger ditches requires installation of various structures. Wood ordinarily is used at first, but concrete should be used if the structures are to be permanent. It

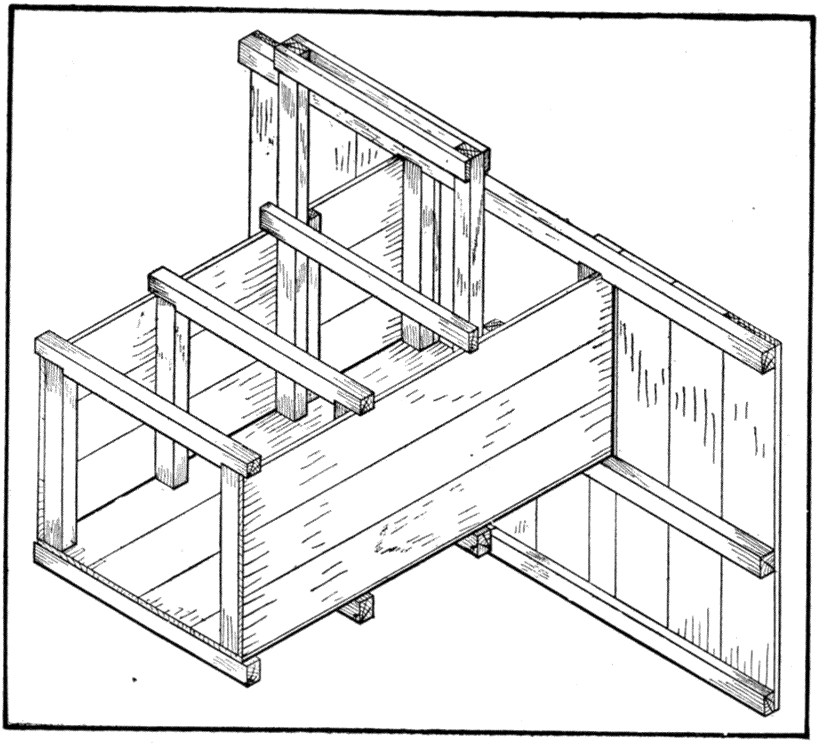


FIG. 7.—Small wooden headgate

often happens that wooden structures can be used until the system has been tested thoroughly. The lumber in these may be used for forms when the time comes to install more permanent concrete works. Wooden boxes usually are put in when a small ditch is taken from a main. (Fig. 7.) Such a structure is made in form of a rectangular box open at the top and may have one, two, or three outlets. The water is controlled best by means of movable boards or slats fitted to slots made by cleats nailed to the side of the box.

Small ditches, however, generally call for structures only at the intake. Elsewhere the water may be controlled either by filling the ditch with dirt at appropriate places and cutting the bank with a shovel or by the use of portable canvas or sheet-iron dams. (Fig. 8.)

In using the canvas dam the irrigator places the top slat across the ditch and throws a little dirt on the canvas at the bottom and sides. The portable sheet-iron dam is used by merely thrusting it into the ditch at right angles to the flow and deep enough to stand the pressure of the water against it.

Water is taken in a number of ways from the small ditches at the head of the furrows. The common way is to cut small trenches through the side of the ditch with hoe or shovel. A better method calls for the use of lath spouts or pieces of pipe set through the banks of the ditch. (Fig. 9.) The amount of water let into the furrow may be regulated either by a cloth flap at the intake of the lath spout or by a shingle thrust into the earth in front of the tile.

TERRA-COTTA PIPE SYSTEMS

A durable and comparatively cheap distribution system may be constructed of terra-cotta sewer pipe, usually called salt glazed vitrified clay pipe. This pipe can be made watertight under low pressure and can be laid by anyone who follows directions carefully. A distribution system of this pipe should not be designed to stand a vertical head of more than 10 to 15 feet or a pressure of more than 4 to 6 pounds per square inch. Therefore, if it is necessary to cross a dip or hollow it is best to cross it with iron, steel, or reinforced-concrete pipe. As is done with open ditches, pipe lines are laid along the highest side of the land to be irrigated and the water is let into the furrows at convenient points. It often is possible to lay the pipe on top of a ridge across a field and run the water down both slopes.

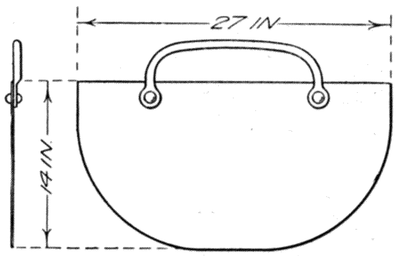


FIG. 8.—Metal dam, or tappoon

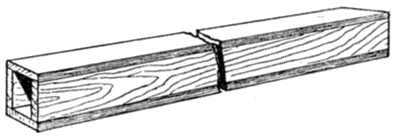


FIG. 9.—Lath pipe for ditch bank

None but the best grades should be accepted when the sewer pipe is bought. Pipe with cracks or broken ends should be rejected. The best way to test for cracks is to tap the pipe lightly with a hammer, a clear ring usually indicating a sound pipe. Pipe which is not well formed also should be discarded; no serious defects, in fact, should be tolerated.

The trench in which the pipe is laid should be dug about a foot wider than the pipe in order to allow the worker to calk and cement the joints carefully. (Fig. 10.) To make the joints watertight it is first necessary to tamp them thoroughly with oakum, which centers the pipe and prevents cement from working into it. After the pipe is laid and the oakum well tamped in, a quantity of clean, sharp sand should be mixed thoroughly with an equal amount of cement, and the mixture wetted to a stiff consistency. This should be forced into the space between the bell and spigot and tamped firmly into place with a tamper, great care being taken to make sure that the

underside of the joint is well cemented. When working with cement it should be remembered that only small batches should be mixed at one time and that these should be used quickly; it is not safe to use mixed cement which has stood longer than one-half hour.

One advantage of a system installed as above is that the pipe may be taken over ridges and across dips, if the total safe head is not exceeded.

The outlet valves or hydrants should be connected to standard vitrified-pipe tees by means of short pieces of clay pipe. Each valve is cemented firmly to the pipe, making a convenient connection with the underground main. Valves are spaced from 30 to 100 feet apart,

FIG. 10.—Laying vitrified-clay pipe to be used for irrigation

and the water is delivered to the furrows either by running it into open trenches and regulating the flow in each furrow with a shovel or by means of portable pipes containing slide gates. These pipes can be fastened to any valve in the field, and usually from 4 to 10 of them will be used simultaneously.

One type of valve which has given satisfactory service is made of cast iron and contains one or two large outlet spouts. (Fig. 11.) This valve it attached by being cemented to the outside of the short riser pipe. It is a valve which allows easy regulation of the quantity of water it discharges, but has the disadvantage of having to be made up on special order when wanted.

Another type of outlet valve, and one more readily obtainable, is illustrated in Figure 12. This valve may be attached to riser pipes of either iron or vitrified clay. It is commonly cemented to the inside of the riser pipe. The valve is closed by placing the cover over the opening and giving it a short quick turn to the left. This causes the two lips on the cover to engage with the inclined lugs on the sides of the valve casting and to clamp the cover tightly onto the top of the upright casting. The valve is opened by simply reversing the process and removing the cover.

When the water is to be conducted away from the valve by ditches or broad flooding, water is simply permitted to spill out over the top in all directions. For cases where it is desired to use slip-joint pipe, a special portable hood is used. This hood clamps to the valve casting in the same way as the cover. It has a sheet-iron elbow, which may be pointed in any direction. Only one portable hood is needed for a large number of valves. This valve has proved very satisfactory in operation. It allows no regulation of the quantity discharged other than complete opening or closing, but this is usually no disadvantage under eastern conditions.

The use of vitrified clay pipe under pressure is generally unwise if the ground freezes to a depth of more than a foot below the sur-

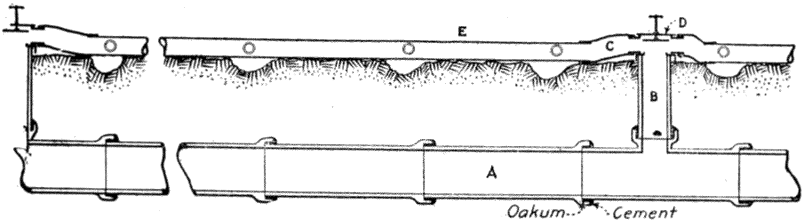


FIG. 11.—Cross-section of typical terra-cotta pipe system. A shows underground terra-cotta main pipe; B, terra-cotta riser; C, canvas connecting house; D, cast-iron valve; E, distributing pipe

face. In any case the top of the pipe should be at least a foot below freezing, as marked changes in temperature apparently cause considerable trouble in vitrified clay pipe even though the pipe be buried below danger from heaving ground. The uprights leading from the main to the surface must be protected, as heaving of the ground due to frost often will break the connection between the valves and the underground main. To prevent this trouble some farmers cover the valves with manure every winter; a better way is to place a large pipe or tile around the riser and fill the space between the two with asphalt, which is sufficiently yielding to protect the riser from being pulled apart in freezing weather.

In northern localities the most common trouble with terra-cotta pipe is the breaking off of valves or the pulling off of vertical vitrified-clay risers from the tees in the main line. This has been overcome by the use of a cast-iron riser which tapers toward the top. The base of this tapered piece of pipe fits in the T at the main as shown in Figure 11, except that where this device is used a block of concrete is built around the T in order to reinforce it. Trouble from heaving ground due to freezing usually develops if a valve such as that shown in Figure 11 rests on the ground. The valve should preferably be several inches above the ground.

Because of the danger of freezing, vitrified-clay pipe when used in the Northern States should be laid on such grades as will permit it to be drained readily. Drain cocks may be placed in the pipe at low places, these being made by cutting holes in the pipe with a chisel and setting in short pieces of 1-inch pipe connected to a cut-off valve. The drain is set near the bottom of the sewer pipe. If there is no natural drainage from the drain cock, it may be necessary to pump the water out before freezing weather sets in.

It is probable that less trouble would be experienced from expansion and contraction breaks in sewer pipe if every third or fourth joint were sealed with bituminous joint filler, such as is used for concrete expansion joints. Where this is done the joint filler is heated and poured into the previously packed joint. This packing is done by tamping firmly into the bottom of the recess strips of newspaper, oakum, or other packing material. A collar is needed

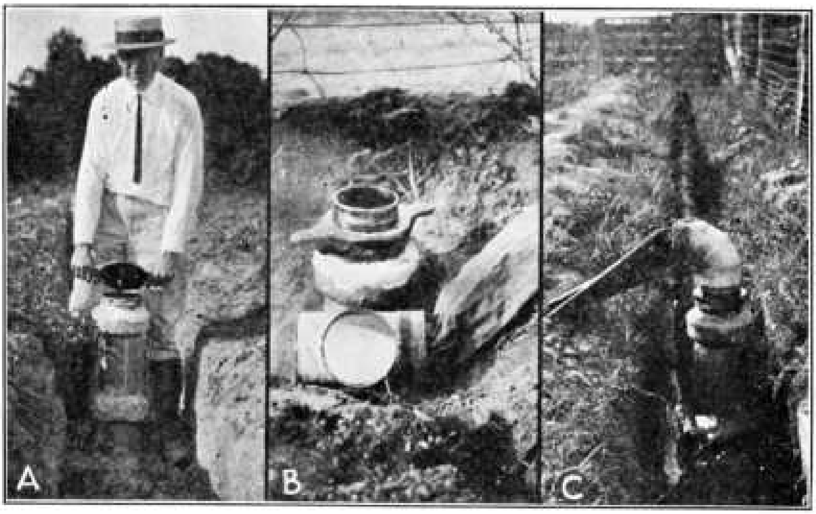


FIG. 12.—Recent design of irrigation valve for terra-cotta pipe system, showing valve, both closed and open, and short riser pipe connecting the valve with the underground main

around the bell while the joint compound is being poured. The joint compound is hard enough to resist considerable pressure and is plastic enough to allow slight lateral expansion and contraction due to changes in temperature.

Often it is possible to use a combination system of vitrified-clay pipe and open ditch, the pipe being used to carry water over rough or gravelly ground or over small ridges or hollows. The ditch then may be used to carry the water over parts of the farm where the grades are uniform and where open ditches would not be in the way of teaming. Water can be taken either out of the ditch or out of the pipe into the furrows, as suggested elsewhere in this bulletin. The combination will often mean a considerable saving in cost of the distributing system and be as efficient as one involving a much more complete use of pipe. This method calls for uniform grades in the field, however, and generally will require somewhat larger pipe than would be the case otherwise, as it will not be possible to have as

much pressure as needed for the pipe alone. This method is not advisable if the soil to be irrigated is so sandy or porous as to cause heavy waste by seepage from an open ditch.

It is never safe to pump directly into a clay-pipe system unless the pipe is reinforced; some sort of relief standpipe must be installed to equalize pressure. Such a standpipe should be placed near the upper end of the land to be watered, and should connect the pressure pipe from the pump with the vitrified-clay pipe distributing system. Standpipes are open at the top, the elevation of which is a few feet above the top of the highest part of the irrigated ground. Thus, if all the valves in the field are closed and the pump is started

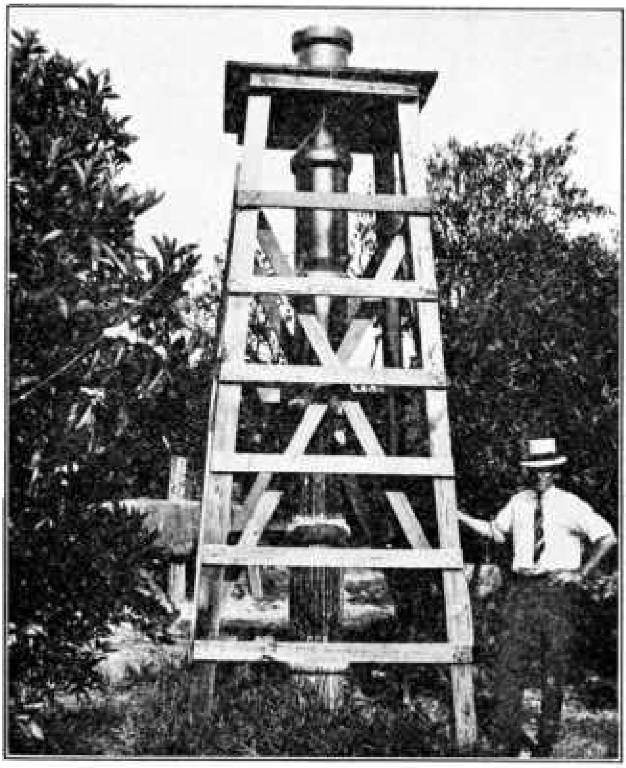


FIG. 13.—Relief standpipe at connection of iron discharge pipe and vitrified-clay distributing lines

the standpipe will permit the water to overflow instead of allowing the pressure to burst the clay pipe. A cheap and convenient standpipe is made by cementing together a few joints of vitrified-clay pipe, as shown in Figure 13. Sometimes standpipes or boxes are constructed in the field to act as diversion boxes. They usually are fitted with slide gates, and serve as air vents as well as means to shift water from one lateral to another.

Several kinds of pipes may be considered where conditions are such as to require considerable pressure (as, for instance, in connecting the pumping plant with the first standpipe). Cast iron probably is the most durable material, but is too costly for use on most farms, as its great weight makes freight and hauling charges excessive.

Galvanized and black wrought-iron or wrought-steel threaded pipe is well adapted to high pressure, but long lines cost a great deal. Lightweight riveted steel pipe, both asphalted and galvanized, is adapted to most eastern conditions. The galvanized pipe is comparatively long lived, but the asphalted pipe often rusts out very rapidly. Wood pipe is not commonly used for irrigation in the humid sections, although well adapted to the purpose. Reinforced concrete pipe or reinforced drain tile or sewer pipe may be used in nearly all cases.

REINFORCED CONCRETE TILE AND SEWER PIPE

High prices of steel and iron pipe and the inability of sewer pipe to stand any but very low heads have led this bureau to make tests on reinforced drain tile for high pressures. Reinforced-concrete pipe has been used for many years in the West to carry water under high pressures. This pipe usually is of the larger sizes and requires special forms and skilled labor to make and lay it. Large-diameter reinforced-concrete pipe can be bought ready made in the East, but heavy freight charges usually prohibit the use of small sizes on the farm. Such pressure pipe is needed in nearly all cases where water is transported from pump to highest point of field, or in crossing deep dips or hollows. The tests, therefore, sought to discover some pipe which any intelligent workman could construct without expensive equipment. From tests made it seems entirely practicable for the farmer to install reinforced-concrete tile, which can be made without any expensive equipment and can be laid continuously in the trench.

Standard clay drain tile was taken first. Several sections of this were placed on a wooden spindle 10 feet long. The sections were then pulled together by six to eight wires running the same way as the pipe. These wires were tightened by means of bolts fastened at regular intervals in a board at the head of the tile. After the vertical wires were tight other wires were wound spirally around the tile, this being accomplished by turning the tile on the wooden core by means of a crank. The spacing of the wires was gauged by hand, one man turning the tile and another holding and guiding the wire. After the tile was wound it was removed from the core and then was ready to be covered with concrete. (Fig. 14.) Ten-foot lengths of tile from 4 to 10 inches in diameter could be handled easily by two men, as the wire held the tile together.

Instead of attempting to place concrete on the tile in a mold or by plastering, the tile was laid continuously in a trench which was cut to such a size that it would act as an outside form for the concrete. For ordinary work the trench was cut to the desired depth and about 3 inches wider than the outside of the tile and the bottom was rounded out to eliminate waste at the corners.

The best way to make a tight, leak-proof tile was found to be as follows: A rich mixture of concrete was made, no gravel or stone over one-half inch in diameter being used. Several inches of the wet mixture was placed in the bottom of the trench, and stones or pieces of broken tile were thrown in. The tile then was placed in the concrete and shaken up and down until the concrete was well stuck to the bottom and part way up the sides, the stone or broken

tile preventing the tile sections from falling to the bottom of the trench. (See title page.) The remainder of the concrete was placed in small quantities with a spade and tamped thoroughly, especially on the sides and around the joints. It was found that the careful placing and tamping of the concrete needed particular attention, in order that leaks might be prevented.

Tile from 4 to 10 inches in diameter was tested, and after the concrete had set it was found that pressures from 25 to 150 pounds to the square inch were needed to break the pipe, the lower pressures being for lean mixtures of concrete and very little reinforcing wire. For pressures up to 50 pounds per square inch for tile over 6 inches in diameter it was found best to use No. 8 wire wound spirally with about 1 inch between spirals. About eight horizontal wires running parallel to the axis of the pipe held the tile together and prevented temperature cracks in the finished pipe. For 4 and 6 inch tile No.

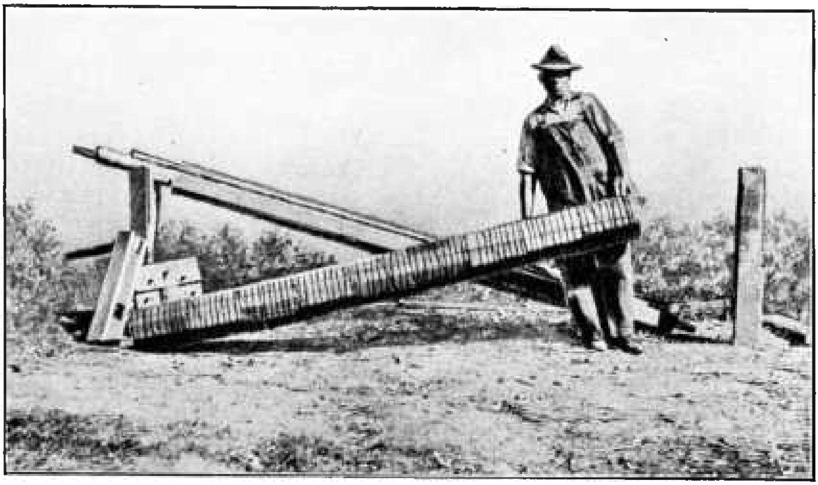


FIG. 14.—Wire-wound tile and wooden core

12 wire with the same wrap was found to answer. Concrete of 1-2-4 or 1-2-3 wet mixture was found to be best.

Such pipe as that described above would be satisfactory for nearly all purposes for surface irrigation where water is pumped. It can be laid continuously for any length and should not cost more than half as much as steel or iron pipe.

Continuous reinforced-concrete pipe was made by following the same general method as that just described, but with this difference: Instead of using tile for a core galvanized-iron pipe was wrapped with wire, laid in the trench, and the concrete placed around it. After the concrete had been allowed to set for about 45 minutes the galvanized-iron core was removed. In order to accomplish this, paper was wrapped around the collapsible core. The wire was wound around pieces of broken tile so as to stand out about 1 inch from the shell of the core and thus be on the outside of the concrete shell. This method requires close attention and should not be attempted on the average farm unless expert help is available. While the cost

of this pipe is less than that of the reinforced drain tile, the difference is comparatively slight.

Another method of making pressure pipe is to use bell-and-spigot vitrified-clay sewer pipe and tamp and cement the joints before wrapping with wire. This pipe is more expensive than tile, but it is easier to make it leak-proof. A reinforced pipe of this sort would be particularly adapted to a sandy soil where it was necessary to use board forms on the sides of the trench. in order to use it for an outside form, where the soil would not permit laying the pipe continuously.

If necessary this pipe could be made in convenient lengths by using forms of wood or clay, the pipe being laid after the concrete had set. This method might be convenient where the pipe could not be laid continuously in the field on account of soil conditions or where freezing weather would prevent outside work. If this method were followed the joints of each length would need to be well wrapped with wire and the concrete poured around the pipe after the lengths had been laid in the trench. It also would be necessary

FIG. 15.—Use of portable galvanized-iron pipe in alfalfa irrigation

to wrap the tile or pipe in shorter lengths, as the finished pipe would be several times as heavy as the wire-wrapped tile.

APPLYING THE WATER TO CROPS

An understanding of the actual use of water in irrigation is as essential as the securing of the supply itself if the investment is to prove profitable. The irrigator must know how to make the water reach the plant roots.

USE OF PORTABLE PIPE AND HOSE

Reference has been made to the use of portable pipe in spreading water which has been brought to the field by other means. If the soil to be irrigated is very sandy or the slope too flat to permit the water to run down the rows or furrows, the use of such pipe may be highly desirable. Portable pipe usually is made in 10-foot sections of light-weight galvanized sheet iron, one end of each section being

slightly tapered, so that it may be pushed into the straight end of the following section to make a fairly tight joint. The pipe should be made of from 24 to 26 gauge galvanized sheet iron for 6-inch and smaller sizes and 22 to 24 gauge for 8 and 10 inch sizes. It is well to reinforce the ends with 18 to 20 gauge iron. Several firms make this pipe; many local tinners can make it or order it for the farmer.

In use the pipe may be built up section by section, or the entire length may be built up first and the sections disconnected as irrigation proceeds. When the end of the field is reached the operation is repeated, with the pipe connected to the next valve, unless it is possible to water a number of rows from one valve. This pipe is very handy for irrigating hay crops and is used extensively in the West for irrigating alfalfa where the soil conditions are not favorable for wide flooding.

FIG. 16.—Six-inch cast-iron irrigation valve and hose connection to slip-joint pipe for irrigating orange grove

It is very difficult to carry water up a grade with the ordinary portable pipe unless special joints are made. Some eastern irrigators have tried to prevent leaks at the joints of cheap portable pipe by laying the pipe on a grade, making use of portable wooden trestles. A better plan is to have the tapered and ringed ends of the sections extra long and heavy and to fit both ends of every joint with lugs. Two bolts can then be put through the lugs and the pipe drawn up with nuts, usually making a fairly tight joint. Western irrigators have used tarred cloth or burlap between the taper and the ring. Another way is to fit a shoulder on one end of the pipe and a rim on the other. A rubber gasket can be used in the shoulder and the pipe pulled together with bolts through lugs, as in the case of the slip-joint pipe.

Where a considerable grade must be climbed it sometimes is necessary to buy extra light weight spiral-riveted pipe and use a bolted

joint. The time necessary to make connections renders this method too slow, however, if the pipe needs to be carried from place to place very often. The necessity of heavily reinforcing the ends of portable pipe in nearly all cases can not be overemphasized, as the pipe often is ruined by breaking of the seams when the sections are connected, bent, or twisted about during irrigation.

Hose is sometimes used instead of portable pipe to convey water, but, as a rule, hose should not be used, as it is not as durable as pipe and is worn out soon by being dragged over the field. It is subject also to attack by insects and rats or mice when stored for the winter, and is hard to handle unless the diameter is small and the lengths are short. Hose will drag down tender plants unless the farmer is very careful in handling it. If used at all, it should be dried out after each irrigation and stored in a dry place.

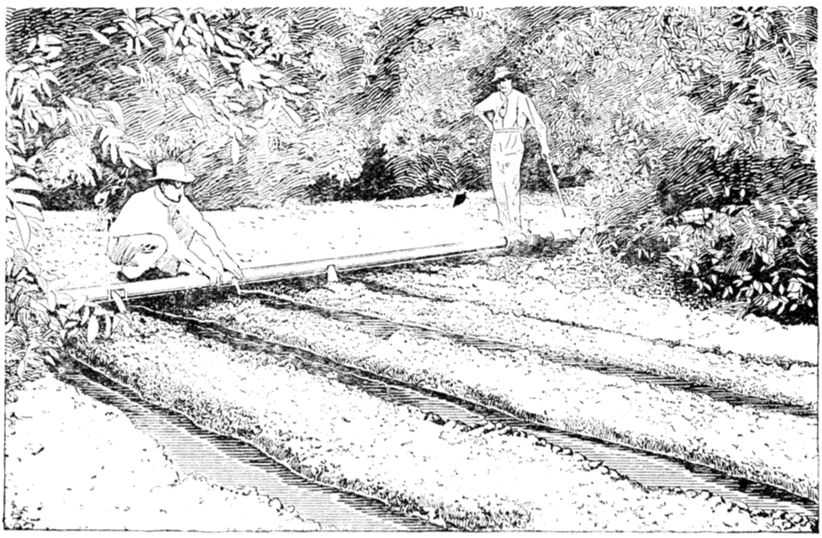


FIG. 17.—Furrow irrigation from portable distribution pipe attached to hydrant of underground main

For small quantities of water ordinary garden hose can be used. Condemned fire hose, up to 2½ inches in diameter, sometimes can be bought cheaply. The connections on this hose are of the quick-turning brass variety. Fifty-foot lengths usually are to be advised. Two to 8 inch hose may be homemade cheaply from strips of heavy duck or canvas by sewing a double seam with very heavy thread. A local harnessmaker or cobbler, having suitable machines for such work, should be able to make a strong hose of this sort. Often it is advisable to treat canvas hose with tar, varnish, or paint to increase its life and render it more nearly leakproof.

Devising connections for home-made hose often presents difficulties. A fairly good joint may be made in several ways, probably the cheapest being to wire the ends to short pieces of light-weight galvanized iron pipe, one end of which is tapered and the other straight. The lengths then are joined as in the case of conductor pipe. If any appreciable pressure is to be applied, these joints should be bolted

together as described for the pipe. A stronger joint can be made by tying the hose around short pieces of standard threaded pipe, a coupling being placed on one end of each pipe. This joint will stand considerable pressure without leaking. Regular brass fire-hose coupling can be bought, but the cost of this for the larger sizes is too high to be considered.

FURROW IRRIGATION

Where the use of portable pipe does not appear to be necessary, irrigation as practiced in the East usually is effected by diverting the water directly from the distribution system into field furrows. (Figs. 18 and 19.) A sandy loam underlain with a comparatively impervious subsoil probably is the easiest and most satisfactory soil to irrigate, provided the slope of the land is favorable. Such a soil with a grade of 4 inches to 1 foot per 100 feet will allow water to

FIG. 18.—Furrow irrigation in Georgia. Water being delivered from cast-iron valve which is connected to underground vitrified clay pipe

reach the plant roots and still run a considerable distance down open furrows. The amount of moisture in the ground before irrigation and the kind of crop grown will go far in determining the quantity of water required. In light, loamy soil this may be applied by running water for a few hours in each furrow, but a much longer time will be required for a heavy soil. Usually water should be let into each furrow and made to reach the lower end as quickly as possible; the quantity entering each furrow then can be diminished, enough still being allowed to enter so that a sufficient supply will reach the end of the furrow. This method may be expected to effect a uniform distribution of the water.

The irrigator can determine whether the water has run long enough by digging down to the roots of the plants and observing how deep

the water has percolated. If it has gone below the root zone a waste is taking place. It is better not to wet the surface of the ground in the row of the plants, but to allow the water to seep into the soil from the furrows, which will prevent the soil in the rows from baking and cracking.

Very sandy soil usually requires a large head of water for each furrow, as it is necessary to get the water to the end of the furrow quickly in order to prevent loss by deep percolation. The slopes of the ground will determine to a great extent the maximum quantity which may be used. If steep slopes are encountered the soils will wash badly and if the ground is too flat the water will not reach the ends of the furrows, but form puddles at the upper ends. The former situation may be controlled by letting smaller quantities of

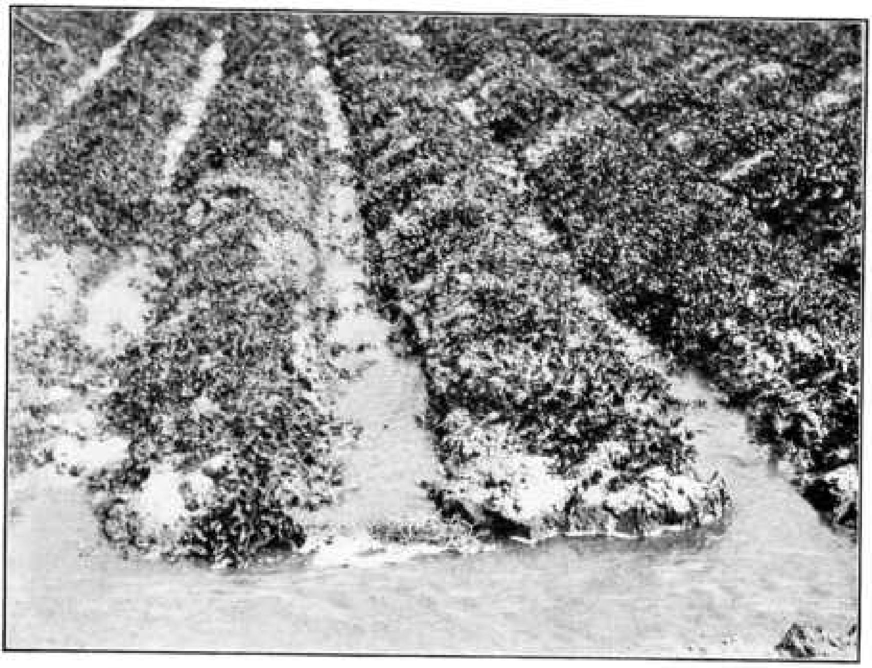


FIG. 19.—Furrow irrigation of sweet potatoes from open head ditch

water into the furrows, or by decreasing their grades by running them diagonally across the field. For very flat grades it often is necessary to use the portable pipe or hose described on page 21.

Heavy clay soils usually require small heads of water in each furrow and the water must be run a longer time. Such soils usually call for less water for an irrigation and also retain water better than the sandy type. However, the irrigator must watch each furrow very carefully or he will waste water at the lower end. For such soil it is especially desirable to have some apparatus that may be adjusted carefully so that the water will be equally divided among a large number of furrows.

Cultivation is very necessary after each irrigation, unless the plants completely shade the ground, and should follow irrigation as soon as the condition of the soil will permit.

Some irrigators plant in the furrow which has been wetted down previously by irrigation; others plant between furrows that are close together, allowing water to run long enough to soak the seed bed thoroughly.

Often furrows 400 to 600 feet long (and sometimes even longer) may be used satisfactorily, but generally shorter lengths are advisable. If the furrows are found to be too long it may be necessary to run another pipe line or ditch parallel to the head one, about halfway down the furrows. In small market gardens the furrows often are not over 100 feet long. These short lengths allow smaller quantities of water to be let into each furrow, and permit close planting.

Where a combination of spray and furrow systems seems necessary, the former should be used to irrigate seed beds or closely planted

FIG. 20.—Flooding between borders with large heads of water

garden truck, and the furrow system for such crops as potatoes, corn, rhubarb, celery, and berries, after they have been set out from the seed beds. It may be practicable to eliminate the spray system by planting the seeds in beds 3 to 10 feet wide which may be irrigated from furrows cut between them. The water should be kept in the furrows long enough to percolate laterally across the beds. This method is practicable on land that is nearly level, and where there is a light surface soil underlain with clay. Furrow irrigation of seed beds on heavy clay soils is very difficult, and requires considerable patience and experience.

When flooding methods are resorted to, it usually is necessary to lay out level beds of convenient size and flood with large heads of water (fig. 20); or in some cases crops may be flooded by cutting the head ditch at convenient points and letting the water run freely

over the land (fig. 21). The former method (which has not been considered in the foregoing discussion) is used in irrigating rice and cranberries and the latter for grain or meadows.

COST OF IRRIGATION

The most important item of expense for irrigation in the humid sections is the cost of installation. This may be only a few dollars per acre where a gravity flow is developed and water is distributed to the field entirely through open ditches. In a number of such cases, especially in the South, considerable areas have been watered for \$10 or less per acre. These systems involve merely short gravity ditches leading directly from streams or flowing wells. A more expensive plant is necessary where the water supply must be stored. Plants utilizing flowing wells that yield only 30 to 40 gallons per minute have been used to irrigate 10 to 20 acres, with the assistance of a storage reservoir constructed in clay soil.

FIG. 21.—Flooding alfalfa field from open field ditch

Irrigation plants involving low pumping lifts and open-ditch distribution systems also are comparatively cheap. Such a plant should irrigate a 20-acre field adjacent to a stream for \$20 to \$35 per acre, if the pumping lift is, say, 25 feet. If a vitrified-clay pipe distribution system were used, the irrigation of the same plat probably would cost \$60 to \$90 per acre. If the pumping lift were 40 to 60 feet, and the field, say, 1,000 feet from the water supply, the total cost easily could be double that given above, although the cost of the distributing system should be about the same as for the system with the lower lift. For a complete system so situated it would be safe to figure a cost of \$100 to \$150 per acre. If a larger acreage were to be watered, the cost would be somewhat less per acre. Where wells must be bored and deep-well pumps installed, an irrigation system

may cost $100 or more per acre. A deep-well outfit usually is too costly for furrow irrigation, unless crop, soil, and market conditions are very favorable.

The following cost tables for pipes of various kinds adapted to use in surface irrigation, together with the pump cost figures shown in Table 2, page 12, and the discussion of engine costs on page 11, should enable a prospective irrigator to estimate, at least approximately, the cost of a complete irrigation system. The prices shown in Table 3 are subject to wide fluctuation.

TABLE 3.—*Approximate cost, per foot of length, of pipe adapted to surface-irrigation systems*

Diameter	Wrought steel, black	Wrought steel, galvanized	Cast iron	Vitrified clay
Inches	*Dollars*	*Dollars*	*Dollars*	*Dollars*
¾	0.06	0.08		
1	.08	.11		
1¼	.11	.15		
1½	.14	.19		
2	.19	.25		
2½	.29	.38		
3	.39	.48		
4	.60	.75	0.70	0.11
5	.82	1.03		.14
6	1.05	1.33	.90	.16
7	1.40	1.90		
8	1.50	2.00	1.30	.25
10	2.10	3.25		.35
12	2.65	3.80	2.20	.45
15				.65
18			3.20	.90

Cast-iron valves for vitrified clay pipe cost $4 to $6 each, and laying and trenching should cost from 8 cents to 12 cents per foot, for the sizes ordinarily used in the East; the higher cost will be in clay soil, where trenching is expensive. Field systems for vitrified-clay pipe installed in the humid sections have cost from $20 to $60 per acre. The cheaper systems sometimes use portable pipe to carry water to some of the higher ridges.

The operating cost of most furrow-irrigation plants in the humid sections is not great, as crops ordinarily need to be irrigated only a few times to carry them through periods of drought. The interest on first cost and the depreciation of the plant must be considered carefully, and often are the deciding factors in determining the feasibility of a pumping outfit. Yearly interest and depreciation of from 10 to 20 per cent is common; probably an average of 15 per cent would hold for most surface-irrigation plants. For example: If a plant cost $75 an acre to install, and the operating cost was $10 an acre per year, it would be necessary to add $11.25 for interest and depreciation, making a total yearly cost of $21.25. This would mean that the crops irrigated should yield a net profit of $21.25 per acre more than those raised on the same land without irrigation before any profit could be accredited to the irrigation plant. Water may be worth many times this amount for some crops and much less for others. Local conditions control allowable costs of irrigation to such an extent that permissible limits of construction expense can not be given here.

INFORMATION NEEDED IN DESIGN OF A PLANT

The Department of Agriculture receives many letters asking for information regarding irrigation in eastern localities. Before helpful advice can be given in response to such requests it is necessary to have the following information:

1. Acreage to be irrigated.
2. Character of the soil.
3. Source of water supply; estimated quantity available. (If a well, the size and type of well, distance to water, and probable draw down when pumped.)
4. Distance from water supply to land to be irrigated.
5. Difference in elevations between land and water supply.
6. Crops to be irrigated.
7. The general grades of the land to be watered.
8. A sketch showing prevailing grades of the land to be irrigated, location of the water supply, etc. It will be sufficient if this indicate approximate contours and directions of slope (by arrow), with fall in inches per 100 feet.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

August 9, 1924

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